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Description

Same-RPM Rotary Motion to Eccentric Rotary Motion Conversion and Waste Product Collection

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. application 09/673,813 filed October 21, 2000, now U.S. Patent 6,634,437 issued October 21, 2003. Said U.S. 09/673,813 is a U.S. national stage application of PCT/US99/08689 filed April 21, 1999, and is a continuation-in-part of U.S. application 09/065,821 filed April 23, 1998, now U.S. Patent 6,009,767 issued January 4, 2000.

BACKGROUND OF INVENTION

[0002] This invention relates generally to the field of rotary-motion sanders, polishers, buffers, carpet cleaners, etc., and specifically to the conversion of rotary motion to eccentric rotary motion without altering the number of revolutions per minute (RPM) of the rotary motion, and to the

collection of dust, water, and similar waste products generated by the aforementioned rotary-motion devices.

[0003] Conventional generic orbital sanders, buffers, polishers and carpet cleaners typically drive a sand plate, polishing brush, sand screen pad, carpet brush / sponge at a low speed -- typically 175 RPM though sometimes as high as 1000 RPM -- in a circular path. This action produces circular scratches on the sanded surface or carpet. Other random orbital sanders or carpet cleaners in existence rely on a high-speed motor to drive an eccentric random action. The action of the high-speed motor is reduced to the desired speed (e.g., 175 RPM) through various mechanical interactions among the gears, shafts, cams, etc. that comprise the sander / cleaner.

[0004] Illustrative of the prior art is U.S. Patent 3,857,206 for a compound-motion machine in which an eccentric shaft (19) rotates about a motor shaft (14) to produce an eccentric rotation, and a secondary motion is produced by a secondary rotation about the axis of the eccentric shaft, using interacting gear wheels (31 and 32). (Column 2, lines 45-57) The eccentric shaft is fixed to, and rotates at the same speed as, the drive shaft. (Column 2, lines 16-20) The motor needed to drive this device must be a

high speed motor on the order of 4000 to 6000 RPM (column 2, line 33), which establishes an eccentric rotation at the motor speed (4000 to 6000 rpm), while the secondary rotation about the eccentric shaft is reduced in speed by virtue of the gear wheel interaction, to perhaps 300 or 600 rpm depending on the gear ratio and the motor speed. The net motion is rotation at the lower speed, with eccentric motion at the higher speed, requiring and being driven by a high speed motor. There is nothing disclosing or suggesting how this might be achieved with a low-speed motor, nor is there anything suggesting or disclosing how to convert the ordinary circular motion of an existing machine to such a compound motion, without having to simply replace the machine entirely. U.S. Patents 4,322,921, 4,467,565 and 4,845,898 all have similar limitations.

[0005] In all of this prior art, an eccentric plate sander is driven by a high-speed (RPM) motor. The eccentric movement is produced directly by the high-speed motor. This high-rotation speed produced by the motor is gear reduced by the gear system into a lower speed rotation. The main drive shaft drives an eccentric drive shaft which in turn drives the gear reduction. This does produce a slow recip-

rocating action, but requires a high-speed input motor and does not lend itself to adaptation to a low-speed input motor. Nor does it enable a pre-existing low-speed machine to be easily adapted to provide high-speed eccentric action.

[0006] Additionally, sanding is typically a very messy job, with dust particles permeating the area being sanded. An inordinate amount of cleanup is required following a sanding job, and it is usually advisable to remove as many movable items as possible from the area to be sanded, prior to sanding, so that these will not become permeated with dust. This introduces much extra work which is preferably avoided. For carpet cleaning, water and other cleaning fluids are applied to the carpet being cleaned, and the rotary motion (or rotary and eccentric motion) is used to create the desired cleansing action. Here, it is often necessary to wait for a day or so for the water and cleaning fluids to dry before using the carpet again, which is inconvenient. Additionally, since much of the dirt being cleaned becomes suspended in the water or cleaning fluid, removal of as much of this water or fluid as possible will simultaneously remove as much dirt as possible. Allowing water or fluid with dirt in suspension to simply dry

on the carpet does nothing to remove that dirt, and results in a cleaning job of much lesser quality.

[0007] It would be desirable to have available a means and method for producing eccentric sanding or cleaning motion using a low-speed (e.g., 125 to 1000 RPM) input motor in which the speed of rotation of the output is precisely the same as the input speed, and in which gear increment -- rather than gear reduction -- is used to convert the low-speed input into a higher-speed eccentric movement.

[0008] Because many lower-speed input (e.g. 125 to 1000 RPM) sanders and cleaners are already in use in the market, it would further be desirable to provide a modular attachment for such sanders and cleaners which converts this lower-speed input into a higher-speed eccentric movement coupled with a rotation identical in speed to the lower-speed input, with minimum use of space and without major modifications to the original sander or cleaner, thereby avoiding the need to purchase a separate high-speed input sander or cleaner in order to achieve this motion and expanding the range of applications that can be performed by a single piece of sanding or cleaning equipment.

[0009] It is further desirable to provide a generic method for converting a lower-speed input of, for example, 175 RPM, into a rotary motion still operating at the example input speed of 175 RPM, but adding eccentric motion at a higher frequency.

[0010] It is further desirable for this method to be applied to other rotating sanding devices in existence such as floor sanding edgers, milling machines, and other low speed grinders, as well as hand drill and other rotary motion devices including carpet cleaners.

[0011] It is further desirable to provide a means and method for removing as much dust as possible during sanding, so that dust cleanup afterward, as well as the removal of movable items beforehand, can be avoided.

[0012] It is further desirable to provide a means and method for removing as much water and cleaning fluid as possible, during carpet cleaning.

SUMMARY OF INVENTION

[0013] This invention uses a low-speed motor input (frequency) to drive a low-speed rotation at the same speed as the motor input, and through gear increment, to drive a much higher-speed eccentric movement. In the prior art, a high-speed motor input is used to drive a similar high-

speed eccentric movement, and through gear reduction, a much lower-speed rotation.

[0014] First, a fixed gear housing of the device is fixed to a fixed (non-rotating) component of a rotary motion machine. Second, a drive shaft of the device is affixed to that component of the rotary motion machine which generates rotary motion of the given input frequency. Through various combinations of gear interactions and secondary (eccentric) motion driving bars, the device adds a higher-frequency eccentric oscillation to the original rotary motion. The net output is a primary rotational motion at the original input frequency, and a secondary eccentric oscillation of substantially higher frequency.

[0015] Waste products such as sand (from sanding) and water / fluids (from carpet cleaning) are collected by attaching a vacuum outlet through the fixed gear housing of the device and through the fixed (non-rotating) component of the rotary motion machine, and by adding a plurality of suction apertures through the pertinent operating attachment and other pertinent components of the machine. A vacuum skirt is used to enhance the suction from the vacuum outlet and to better contain dust and water.

BRIEF DESCRIPTION OF DRAWINGS

[0016] The features of the invention believed to be novel are set forth in the appended claims. The invention, however, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawing(s) in which:

[0017] FIG. 1 shows cross-sectional side and bottom-up plan views of the manner in which a sanding, polishing, buffing, or cleaning disk is ordinarily attached to the drive clutch of a rotary-motion sanding or cleaning machine, in the prior art.

[0018] FIG. 2 shows cross-sectional side and bottom-up plan views of the preferred embodiment of the invention, using two moving gears.

[0019] FIG. 3 shows the geometric constructions utilized to calculate the geometric trajectory over time of a particular "grit" of the sanding, buffing, polishing or cleaning attachment in the preferred and alternate preferred embodiments of the invention.

[0020] FIG. 4 shows a bottom-up plan view of a first alternative preferred embodiment of the invention, using four moving gears.

[0021] FIG. 5 shows side and bottom-up plan views of a second

alternative preferred embodiment of the invention, using a driving disk.

[0022] FIG. 6 shows a side plan view of a third alternative preferred embodiment of the invention which further increases the eccentric motion frequency of the invention.

[0023] FIG. 7a illustrates a side perspective view of a rotary-motion sanding or cleaning machine, a side plan view of the invention embodiment of FIG. 2, and the manner in which the invention (all embodiments) is connected to the sanding or cleaning machine for use.

[0024] FIG. 7b is a bottom-up plan view along the lines 7b--7b of FIG. 7a, of the manner in which the invention (all embodiments) is connected to the sanding or cleaning machine for use.

[0025] FIG. 8 illustrates a side perspective view of the rotary-motion sanding or cleaning machine of FIG. 7a, and a side plan view of the invention embodiment of FIG. 2, as modified with a vacuum attachment for dust (sanding) and water (cleaning) removal.

Detailed Description

[0026] FIG. 1 shows how a sanding, polishing, buffing or carpet cleaning disk is ordinarily attached to the rotary motion component *102* such as the drive clutch of a rotary-mo-

tion sanding or cleaning machine *7* of FIG. 7, in the prior art. As shown in cross-sectional side view in the upper part of FIG. 1, conventional rotary sanding or cleaning machines are set up for sanding, buffing, polishing or cleaning by attaching (mating) a sanding, buffing, polishing or cleaning disk attachment (henceforth referred to as operating attachment *101*) to input rotary motion component *102* of the sander or cleaner, by inserting input rotary motion component *102* into an attachment receptacle *103* of operating attachment *101* as shown by arrow *105*. Often, the mating proceeds by first inserting input rotary motion component *102* into attachment receptacle *103* and then twisting one relative to the other until they lock together. This manner of mating, and its variations, are well known in the art and so needn't be elaborated herein. Attachment receptacle *103* inserts firmly around input rotary motion component *102* as known in the art so that when the sanding or cleaning machine *7* is activated, input rotary motion component *102* will begin to rotate at the input speed (RPM) of the sanding or cleaning machine motor along the direction indicated by (right-hand rule) arrows *104*. (Of course, left-hand motion is equally encompassed.) Thus, by virtue of this mating, the entire operat-

ing attachment *101* will similarly rotate concentrically at this same motor input speed, as shown from bottom-up view by arrow *108* illustrating the primary orbital motion direction. Also illustrated is a primary rotational centerline *106*, and operating attachment center *107*.

[0027] FIG. 2 illustrates the preferred embodiment of the invention. Note that the use of "primes" in the component numbering will be used to denote analogous structure and / or function to the prior art structures and / or functions as illustrated in FIG. 1. Rotary-motion conversion module *2* attaches (mates) to input rotary motion component *102* via a conversion module receptacle *103'* which is substantially identical to attachment receptacle *103*, and which mates to input rotary motion component *102* as shown by arrows *105'* in a manner substantially identical to the mating earlier described in FIG. 1 between input rotary motion component *102* and attachment receptacle *103* according to arrows *105*. Thus, a shaft driving disk *101'* which occupies the same position with respect to input rotary motion component *102* as operating attachment *101* of FIG. 1 will be caused to rotate according to arrows *104* once the sanding or cleaning machine *7* is turned on.

[0028] Operating attachment *101*, on the other hand, attaches

(mates) to pass-through rotary motion component means *102'* of conversion module *2*, which is substantially identical in structure to input rotary motion component *102*. Similarly, the method of mating attachment receptacle *103* to pass-through rotary motion component *102'* according to arrows *105"* is substantially identical to the method of mating conversion module receptacle *103'* to input rotary motion component *102* according to arrows *105'*, and to the prior art method of mating attachment receptacle *103* to input rotary motion component *102* according to arrows *105* as in FIG. 1. Because a variety of such mating methods are known in the prior art, this disclosure and its associated claims are intended to fully encompass this variety of mating methods as used within the scope of this invention, and is not dependent on any one or another of these mating methods. However, while shaft driving disk *101'* rotates concentrically about primary centerline *106* at the input frequency (RPM) of the sanding device motor, operating attachment *101* does not follow this same concentric rotation. Rather, due to the motion-conversion mechanism to be described below, operating attachment *101* no longer exhibits concentric rotation. Instead, its primary rotation is at the same speed at the input motor, but a

secondary, higher-speed eccentric motion is also introduced.

[0029] To convert the concentric rotary input motion *104* to an eccentric rotary output motion, shaft driving disk *101'* is integrally affixed to a drive shaft *201* which runs substantially through the center of a fixed gear housing *202* and substantially through the center of a non-rotating center gear *203* immovably affixed to fixed gear housing *202*. The region above fixed gear housing *202* and center gear *203* in FIG. 2 will be generally referred to as the "input region" of the housing; while the region below housing *202* and center gear *203* will be referred to as the "output region" of the housing. Drive shaft *201* at its lower extremity (in the output region) is further integrally affixed to a lateral driving connector *204* as shown. In this illustration, lateral driving connector *204* is a driving bar extending laterally within fixed gear housing *202* as shown, though other embodiments for lateral driving connector *204* are also possible, as will be shown later. Drive shaft *201* rotates within fixed gear housing *202* and non-rotating center gear *203*, with bearings and / or appropriate lubricants provided at the surfaces indicated by thicker drawing lines, to facilitate that rotation.

[0030] Fixed gear housing *202*, importantly, is fixed so that it does not in any way rotate in response to the rotation of input rotary motion component *102*. This is achieved by means of a housing fixing device *205* which in the preferred embodiment is an attachment arm as shown. This arm is fixed to the bell of the sanding or cleaning machine *7* as shown and later described in more detail in FIGS. 7a and 7b, so as to prevent fixed gear housing *202* from rotating, i.e., to render fixed gear housing *202* independent of the rotation of input rotary motion component *102*. For other applications, e.g., to convey the rotary motion of a drill into an eccentric rotary motion, the housing fixing device might affix the housing, e.g., to the drill handle. While implementation may thus vary for different applications and devices, the key point is that fixed gear housing *202* is prevented from rotating by affixing it to a non-rotating component of the machine *7* providing the rotary input motion. Non-rotating center gear *203* similarly does not rotate because it is integrally affixed to fixed gear housing *202*. Thus, the rotation of input rotary motion component *102* at a given RPM causes shaft driving disk *101'*, drive shaft *201* and lateral driving connector *204* to rotate at the same RPM as the input drive, while non-

rotating center gear *203* remains fixed with respect to this rotation.

[0031] To add eccentric motion, the teeth of a pair of rotating outer gears *206* engage the teeth of non-rotating inner gear *203* as shown. Secondary drive shaft means *207* are integrally affixed to rotating outer gears *206* as shown, so as to rotate with the same frequency as outer gears *206*. Secondary drive shafts *207* also pass through and are free to rotate with respect to lateral driving connector *204*, with bearings and / or appropriate lubrication provided at the region again illustrated by the thicker lines to facilitate free rotation. Eccentric motion driving bar means *208* are integrally affixed to secondary drive shafts *207*, and so also rotate at the same frequency as outer gears *206*. Finally, a pair of eccentric motion drive shafts *209* are integrally affixed to secondary driving bars *208*, again, so as to also rotate with the same frequency as outer gears *206*. The combined means comprising components *206*, *207*, *208* and *209*, which is responsible for introducing the eccentric motion into the system, shall be generally referred to as "eccentric motion generating means."

[0032] Eccentric motion drive shafts *209*, are in turn tapped into a composite motion pass-through means *210* such as the il-

lustrated disk, allowing free rotational movement of eccentric motion drive shafts *209* within composite motion pass-through means *210*, again, with bearings and / or appropriate lubrication at the region illustrated with thicker lines. Pass-through rotary motion component *102'* is affixed proximate the center of composite motion pass-through means *210*, and so when operating attachment *101* is finally attached to pass-through rotary motion component *102'* via rotary motion receptacle *103* as per arrows *105''*, as described earlier, the motion imparted to operating attachment *101* will be that of composite motion pass-through means *210* and pass-through rotary motion component *102'*, rather that of input rotary motion component *102*.

[0033] The eccentric motion is introduced, in particular, by eccentric motion driving bar means *208*, and generally by the eccentric motion generating means comprising components *206*, *207*, *208* and *209*. The magnitude of the eccentric motion is directly proportional to the displacements *211* between the center of secondary drive shafts *207* and the center of eccentric motion drive shafts *209*. By virtue of the connections outlined above, the rotation *104* of input rotary motion component *102* is imparted directly

to lateral driving connector *204* via drive shaft *201* and shaft driving disk *101'*. The rotation of lateral driving connector *204* causes secondary drive shafts *207* to rotate (orbit) concentrically about primary centerline *106* along arrow *108*, while the interaction between rotating outer gears *206* and non-rotating center gear *203* further causes rotating outer gears *206* to rotate (spin) about secondary rotational centerlines *212* along the path illustrated by (right-hand-rule) arrows *213*. From the bottom-up view, the rotation of outer gears *206* about secondary rotational centerlines *212* is as shown by arrows *214*. This rotation (spin) of outer gears *206* is further imparted to secondary driving bars *208* and, via eccentric motion drive shafts *209*, ultimately to composite motion pass-through means *210*, pass-through rotary motion component *102'*, and operating attachment *101*.

[0034] In particular, composite motion pass-through means *210*, pass-through rotary motion component *102'*, and operating attachment *101* are imparted a net composite motion that captures both the orbit of rotating outer gears *206* about primary centerline *106* (primary orbital motion *108*), and the spin of outer gears *206* about secondary rotational centerlines *212* in combination with the eccentric dis-

placements *211* introduced by eccentric motion driving bars *208* (secondary eccentric motion *214*). Note that it is the boring of drive shaft *201* directly through the fixed gear housing *202* and center gear *203* and its rotation therein that serves to impart to operating attachment *101* a primary orbital motion *108* that is identical in speed (RPM) to input motion *104*.

[0035] If the input frequency (RPM) *104* of the motor is designated by Ω (e.g. 175 RPM for a typical low-speed sander), then the primary orbital motion will be at precisely this same frequency Ω because of the manner in which drive shaft *201* passes straight through the center of center gear *203* and causes outer gears *206* to orbit about center gear *203*. If the number of teeth upon center gear *203* is designated generally by N (N=61 in FIG. 2), and upon outer gear by n (n=30 in FIG. 2), then the frequency ω of the secondary eccentric motion will be stepped up by the ratio N/n, i.e.,

[0036] $\omega = (N/n) \times \Omega$, (1)

[0037] with both rotations (*214* and *108*) occurring in the *same* direction. Thus, in the illustration of FIG. 2 (by way of example, not limitation), if Ω = 175 RPM clockwise, then $\omega = 61/30 \times 175$ RPM ≈ 356 RPM clockwise. Circular path

213 is thus illustrated with two arrows, while path *104* is illustrated with but a single arrow, to denote this step up in frequency (i.e., that *213* is a higher-frequency rotation that *104*). For a one gear-interaction system such as that of FIG. 2, the step up in the eccentric frequency over the primary frequency is thus determined generally by the gear ratio N/n, though this step up can be further enhanced through multiple gear interactions, as will be later illustrated in connection with FIG 6.

[0038] To maximize sanding, polishing or buffing variation, it is also desirable to choose the number of teeth on each gear so as to introduce the longest possible time (maximum number of cycles) before a particular "grit" upon operating attachment *101* returns to the same radial and angular location (position). In FIG. 2, starting at a given initial position, it requires n=30 revolutions of outer gears *206* about center gear *203*, and, simultaneously, N=61 rotations of outer gears *206* about secondary rotational centerlines *212*, before a particular grit returns to its original position. Had N been chosen to be 60, rather than 61, then because 60 is evenly divisible by 30, a given grit would return to precisely the same position with every revolution of outer gears *206* about center gear *203*, which is not desirable.

Generally, gear ratios should thus be chosen so as to avoid common divisible factors. The use of prime number gear counts is helpful in this regard, as this by definition avoids common (indeed any) divisible factors.

[0039] Also, it is possible, alternatively, to replace center gear *203* (which has teeth facing radially-outward) with a gear having teeth facing radially inward, running to the *outside* of outer gears *206*, and engaging the teeth of outer gears *206* along the dotted gear line indicated by *215*. In this configuration, outer gears *206* would then spin about secondary centerlines *212* in a direction *opposite* their revolution about primary centerline *106*. That is, *214* would run opposite *108*. This naturally introduces a higher gear gain ratio (N/n), because of the larger circumference of gear *215* compared to gear *203*.

[0040] FIG. 3 depicts an arbitrarily-selected position of operating attachment *101* during operation. Point P is a randomly-selected grit on operating attachment *101*, R designates the radial distance of point P from the center *107* of operating attachment *101*, and θ designates the angular orientation of point P with respect to operating attachment center *107*. Recalling that the mechanism of FIG. 2 causes lateral driving connector *204* and hence secondary drive shafts

207 to rotate about the center of drive shaft *201* at the input frequency Ω, it is apparent that the geometric (not physical) point labeled as "constant Ω" in FIG. 3 -- constructed at the denoted distance r and angle ϕ with respect to P, is a point that rotates about the center of motion of drive shaft *201*, at a constant frequency and speed given by input frequency Ω. By geometric construction, this point of constant Ω is oriented at the same angle θ with respect to the center of drive shaft *201* as point P is oriented with respect to operating attachment center *107*. Thus, point P moves about the center *107* of operating attachment *101*, and the point labeled constant Ω also moves about the center of drive shaft *201*, over time t, at the constant input frequency Ω, with an angular orientation over time t given by:

[0041] $\theta(t) = 2\pi\Omega t$. (2)

[0042] Similarly, if ϕ designates the angular orientation of secondary driving bars *208* as shown, it is to be recalled that this orientation will also move with constant angular frequency ω as given eq. 1, that is:

[0043] $\phi(t) = 2\pi\omega t = 2\pi G\Omega t = 2\pi(N/n)\Omega t$, (3)

[0044] where $G = N/n$ is the gear gain ratio. Finally, r is used to

designate the eccentric displacements *211* (see also FIG. 2) introduced by eccentric motion driving bar means *208*.

[0045] With all of the above, one can readily calculate the (x,y) coordinates of point P with respect to the origin of rotation at the center of drive shaft *201* to be:

[0046] $P(x,y) = P(R \cos \theta + r \cos \phi, R \sin \theta + r \sin \phi)$ (4)

[0047] Thus, if R' designates the radial distance, and θ' designates the angular orientation, of point P with respect to the *center of drive shaft 201*, i.e., primary centerline *104* (rather than operating attachment center point *107*), one can readily calculate that:

[0048] $R' = \mathrm{sqrt}\,[R^2 + r^2 + 2Rr \cos (\theta - \phi)]$ (5)

[0049] and

[0050] $\sin \theta'(t) = (R \sin \theta + r \sin \phi) / \mathrm{sqrt}\,[R^2 + r^2 + 2Rr \cos (\theta - \phi)]$. (6)

[0051] To express these over time rather than in terms of angles, one merely substitutes eqs. (2) and (3) into eqs. (5) and (6) above, to yield:

[0052] $R'(t) = \mathrm{sqrt}\,[R^2 + r^2 + 2Rr \cos (2\pi(G-1)\Omega t)]$ (7)

[0053] and

[0054] $\sin \theta'(t) = (R \sin 2\pi\Omega t + r \sin 2\pi G\Omega t) / \mathrm{sqrt}\,[R^2 + r^2 + 2Rr$

$\cos(2\pi(G-1)\Omega t)]$. (8)

[0055] In contrast, for the prior art configuration of FIG. 1 (which is the limiting case in which r=0 in eqs. 7 and 8 above), $R'(t) = R$ (constant radius), and $\theta'(t) = 2\pi\Omega t$ (constant frequency).

[0056] FIG. 4 shows a bottom-up plan view of a first alternative preferred embodiment of the invention. This embodiment is substantially the same as the preferred embodiment shown in FIG. 2, however, lateral driving connector *204* is now a driving "cross" as shown, attaching two additional rotating outer gears *206* with all other pertinent elements (e.g., *207*, *208*, *209*) as shown, in the same manner as earlier discussed in connection with FIG. 2. Thus, while FIG. 2 illustrates a two-moving gear system, FIG. 4 illustrates a four-moving gear system. The use of four gears, rather than two, may provide a preferred weight balance for some applications. It should be apparent by contrasting FIG. 4 with FIG. 2 that the number of moving gears can readily be varied, and that the invention can be constructed even with but a single moving gear if needed, simply by altering the configuration of lateral driving connector *204*. Thus, e.g., for a three-moving gear system, lateral driving connector *204* could have "triangular" arms

each emanating about drive shaft *201* at substantially 120 degrees from one another. For five gears, an angle of substantially 72 degrees could separate the arms and the moving gear, etc. Any such variations in the number of moving gears would fall within the scope of this disclosure and its associated claims. Available physical space is the only limiting factor in choosing the number of moving gears. The motion of the device is still calculated according to eqs. 7 and 8, is unaffected by the number of moving gears, and depends only upon gear gain ratio G, eccentric displacement r, and input frequency Ω.

[0057] FIG. 5 illustrates a second alternative preferred embodiment of the invention which is somewhat similar to FIG. 4, insofar as it is also a four-moving gear system. However, in this embodiment, lateral driving connector *204* is now a driving "disk" as shown, wherein secondary drive shafts *207* of rotating outer gears *206* pass through this driving disk-type lateral driving connector *204* at substantially 90 degrees from one another similarly to FIG. 4. (Again, one can use a different number of outer gears *206* within the scope of this disclosure and its associated claims.) Additionally, shaft driving disk *101'* and drive shaft *201* are combined into a single indistinguishable component,

wherein drive shaft *201* is substantially widened in relation to its width in FIG. 2, and affixes to lateral driving connector *204* along a much larger contact region as shown. The bore through the center of a non-rotating center gear *203* thus has a much larger radius to accommodate the wider shaft *201*. Thicker, dashed lines continue to indicate regions where rotational bearings and / or sufficient lubrication is required to facilitate rotation.

[0058] In heavy use, the region where drive shaft *201* affixes to lateral driving connector *204* undergoes perhaps the highest degree of physical torque-related stress. In the configuration of FIG. 5, because drive shaft *201* affixes to lateral driving connector *204* along a much larger region, the chance that drive shaft *201* might break off from lateral driving connector *204* under a high-torque stress is greatly reduced. In addition, given the manner in which this overall rotary-motion conversion module *2* attaches to a sanding machine *7* (see FIGS. 7), it is desirable to minimize the vertical height of module *2* as much as possible. The configuration of FIG. 5 helps to further achieve as "flat" a module *2* as possible.

[0059] It was noted in connection with FIGS. 2 and 3 (see also eqs. 1 and 3) that the eccentric motion frequency ω is

stepped up by a factor of gear gain ratio G with respect to the input motor frequency Ω, i.e., that $\omega = G \times \Omega$. In a configuration such as that shown in FIGS. 2, 4 and 5, with a single set of rotating outer gears *206* (regardless of how many gears comprise this set), then if N = N(*203*) is the number of teeth in non-rotating center gear *203*, and n = N(*206*) is the number of teeth in each of the rotating outer gears *206* engaging center gear *203*, then, as noted earlier, gear gain ratio G = N/n = N(*203*)/N(*206*). The motion of a single grit is then parameterized in terms of time t, using ratio G, by eqs. 7 and 8. In many cases, the gain ratio G achieved through the configuration of FIGS. 2, 4 and 5 is perfectly acceptable. However, if it is desired to greatly magnify the input frequency Ω into a very high eccentric motion frequency ω (for example, by a ratio of 10 to 1 or more), then a configuration such as that shown in FIG. 6, or something similar thereto that can be deduced by someone of ordinary skill in the mechanical arts, can be used to achieve this.

[0060] FIG. 6 is illustrated based on the two outer gear, driving bar embodiment of FIG. 2. However, it would be obvious to someone of ordinary skill and is within the scope of this disclosure and its associated claims to apply the dis-

closure of FIG. 6 to work in connection with the four-gear embodiments of FIGS. 4 and 5 as well, or with obvious variations of the embodiments in FIGS. 2, 4 and 5 (e.g., one, three, five and six gear systems, etc.), subject only to physical space limitations.

[0061] FIG. 6 has all of the same elements and interactions as FIG. 2, and is driven and connected to the sanding machine *7* of FIG. 7 in precisely the same way. However, within the eccentric motion generating means, rotating outer gears *206* are replaced by stacked outer gears *206'* and *206"*, and drive shaft *201* drives a lateral driving connector *204* with two parallel, vertically separated, laterally extending bars. If one started with FIG. 4 or 5 rather than FIG. 2, then lateral driving connector *204* would utilized parallel "crosses" (FIG. 4) or parallel "disks" instead. While FIG. 6 illustrates a two-layer stacking, this can be generalized by someone of ordinary skill to multiple layers as desired, or to other gear-increment configurations known in the art, subject only to space limitations.

[0062] When input rotary motion component *102* rotates drive shaft *201* as earlier described, the upper driving connector of *204* rotates upper outer gears *206'* in precisely the same way that outer gears *206* are rotated in FIGS. 2, 4 and 5,

with a stepped-up frequency ω given by eq. 1. However, secondary drive shafts *207*, secondary driving bars *208* (which introduce the eccentric motion radius r (*211*) of eqs. 1-8) and eccentric motion drive shafts *209* are now affixed to lower outer gears *206"*, rather than outer gears *206* as in FIGS. 2, 4 and 5. Newly-introduced are first step-up gears *601*, second step-up gears *602*, and third step-up gears *603* (one for each outer gear pair *206'* and *206"*), which further multiply the rotational frequency imparted to secondary drive shafts *207*, eccentric motion driving bars *208* and, particularly, eccentric motion drive shafts *209*, as follows.

[0063] First step up gears *601* are immovably affixed to upper outer gears *206'* via first step-up gear connectors *604* which run through the upper driving connector of *204* just as secondary drive shafts *207* runs through driving connector *204* in FIGS. 2, 4 and 5. (Thick, dotted lines again indicate rotational regions where bearings and / or sufficient lubrication are required.) Thus, first step up gears *601* will be imparted the same frequency of rotation as upper outer gears *206'*. The direction of rotation (based on primary input rotation *104*) is illustrated by the arrows, and the presence of two arrows on each of *206'* and *601*

indicates that these each rotate at the same frequency, but that this frequency is already stepped up from the input frequency θ indicated by the single arrow on *104*. However, first step up gears *601* have a larger radius -- and more importantly, more teeth -- than upper outer gears *206'*. The teeth of first step up gears *601* then engage teeth of second step-up gears *602*, which have a smaller radius -- and more importantly, less teeth -- than first step up gears *601*. Thus, second step-up gears *602* rotate at an even higher frequency (with opposite direction) than first step up gears *601*, as illustrated by three arrows rather than two. Second step-up gears *602* are in turn attached directly to third step-up gears *603* with larger radius and more teeth, which by virtue of this attachment will rotate at the same frequency and in the same direction as second step-up gears *602*. The combined element comprising *602* and *603* is fixed in place by upper step up attachments *605* and lower step up attachments *606*, which respectively bore into and rotate freely within the upper and lower arms (or crosses for FIG. 4 and plates for FIG. 5) of driving connector *204*, as shown.

[0064] Finally, the teeth of third step-up gears *603* directly engage the teeth of lower outer gears *206"*, which have a

smaller radius and less teeth than third step-up gears *603*. Thus, lower outer gears *206"* will rotate at an even higher frequency (and reverse direction) than third step-up gears *603*, as now illustrated by four arrows. Lower outer gears *206"*, of course, drive secondary drive shafts *207*, eccentric motion driving bars *208* and eccentric motion drive shafts *209*, and thus, the frequency of eccentric rotation *213* (also now showing four arrows) is the same as that of lower outer gears *206"*. Note that lower outer gears *206"* are connected on top into a bore on the lower portion of first step up gears *601*, via lower outer gear attachments *607* that rotate freely within this bore. On the bottom, lower outer gears *206"* are connected through the lower arms (or crosses for FIG. 4 and plates for FIG. 5) of driving connector *204* with secondary drive shafts *207* just as in FIGS. 2, 4 and 5. The connections achieved by components *604*, *605*, *606*, *607* and *207* ensure that the primary rotational frequency Ω (*104*) is preserved and passed through to operating attachment *101*. The free rotation permitted by these same components, however, further enables the secondary (eccentric) frequency *213* to be vastly stepped up.

[0065] In particular, if N(*203*), N(*206'*), N(*601*), N(*602*), N(*603*) and N(*206"*) denote the number of teeth for the particular

gears associated with the parenthetical numbers, then the step up gear ratio G, which was G = N/n = N(*203*)/N(*206*) for FIGS. 2, 4 and 5, is, for FIG. 6, now given by:

[0066] $G = [N(203)/N(206')]x[N(601)/N(602)]x[N(603)/N(206'')]$ (9)

[0067] Thus, even with an approximate 2 to 1 ratio for each gear interaction, the eccentric frequency can be stepped up by a factor of $2^3 = 8$, and with a 3 to 1 ratio, this provides a factor of 27 to 1. Generally, with a G' to 1 ratio for each gear interaction, $G = G'^3$. The overall motion of a given "grit", however, is unchanged from that of eqs. 1-8; all that changes is the gear gain ratio G. Thus, the motion of a grit on operating attachment *101* in FIG. 6 is described simply by substituting eq. 9 for G into eqs. 1-8 as appropriate.

[0068] FIGS. 7 illustrates how rotary-motion conversion module *2* from any and all of FIGS. 2, 4, 5 and 6 attaches to sanding, carpet cleaning, or similar machine *7*. For illustration, not limitation, module *2* of FIG. 2 is used in FIG. 7. FIG. 7a depicts a conventional sanding or cleaning machine *7* with a bell *71* and a user control shaft *72*. Illustrated with hidden lines within the sander or cleaner *7* is input rotary motion component *102* which was earlier illustrated at the top of each FIGS. 1, 2, 5 and 6. Rotary motion component

102 rotates in direction *104* at input frequency Ω as has been discussed all along, and is driven by a sander motor (not shown) in a manner well known in the art.

[0069] To modify a preexisting sanding or cleaning machine *7* of input frequency Ω to accept rotary-motion conversion module *2*, one first affixes a housing fixing device receptacle means *73* directly to the bell *71* as shown in both FIGS. 7. Receptacle means *73* can be screwed into the bell, welded thereon, or attached (permanently or removably) in any other way that is known in the attachment arts. What is important, however, is that this attachment be very secure, and that it not come loose when subjected to the shear stresses that are introduced once conversion module *2* is attached to sanding machine *7* and operated.

[0070] Next, one inserts and locks (*105'*) shaft driving disk *101'* into input rotary motion component *102* via attachment receptacle *103'*, as first described in connection with FIG. 2, and later in connection with FIGS. 4, 5 and 6. At the same time, one locks housing fixing device *205* into housing fixing device receptacle means *73* as illustrated by arrow *74* in FIG. 7a, and as shown from bottom view in FIG. 7b. While housing fixing device *205* is illustrated herein as an attachment arm and housing fixing device receptacle

means *73* is illustrated as a "U" to which housing fixing device *205* mates, any configuration is acceptable so long as these two components mate securely to one another without danger of becoming disconnected during operation, so that the fixed gear housing *202* does not rotate during operation. Finally, one chooses operating attachment *101* and attaches (*105"*) it to pass-through rotary motion component *102'* via rotary motion receptacle *103*, as first discussed in connection with FIG. 2 and also later discussed for FIGS. 4, 5 and 6. At this point, conversion module *2* is fully ready for operation.

[0071] Because housing fixing device *205* is locked into housing fixing device receptacle means *73*, fixed gear housing *202* and non-rotating center gear *203* which are integrally attached thereto are prevented from moving in a rotational direction. This enables the outer gears *206* (or *206'* plus assorted step up gears from FIG. 6) to engage center gear *203* and produce the input frequency rotational motion with higher frequency eccentric oscillation described throughout this disclosure, and quantified by eqs. 7 and 8.

[0072] The various configurations described above can be used generally to convert a rotary motion input of given fre-

quency Ω with no eccentricity, into rotary motion of the similar primary frequency Ω, compounded with eccentric motion at a stepped-up frequency $\omega=G\Omega$, and described in detail by eqs. 7 and 8. This is true whether the subject invention is embodied as a module to be attached to a preexisting rotary motion machine (as presented in detail herein), or is embodied directly, non-removably, within a given machine as a way of generating high-frequency eccentric oscillations from a lower-frequency input rotation motor. Either alternative is encompassed by this disclosure and its associated claims. Of course, stepped-down eccentric motion can also be achieved if desired, by appropriate alteration of gear ratios.

[0073] While this discussion has referred generally to a sanding or cleaning machine *7* as the device to which this invention is applied, it is understood that this invention can be used in connection with any rotary motion machine for which it is desired to introduce a (higher-frequency) eccentric oscillation. In all cases, what is needed are simply two points of contact with that machine. First, the fixed gear housing *202* must be fixed to some fixed (non-rotating) component of the machine via a housing fixing means that serves the function of component *205*.

Second, the drive shaft *201* must be affixed to (driven by) that component of the machine which generates the rotary motion, such as input rotary motion component *102*. Thus, for example, a modified version of this device using all of the principles outlined herein can be non-rotatably fixed (*205*), say, to the arm of a standard power drill, with its drive shaft *201* driven by the rotational output of the drill. With, for example, an operating attachment *101* that is a buffer, and with pass-through rotary motion component *102'* designed to accept drill attachments in the same manner that the drill itself normally accepts these, the drill can then be used to provide rotating buffing with eccentric oscillations. This also has application, for example, not limitation, to milling machines and low-speed grinding machines.

[0074] FIG. 8 illustrates how a sanding or cleaning machine *7*, including but not limited to the various embodiments of the invention disclosed thus far, is modified to enable a vacuum attachment that can be used to collect dust and other waste matter created when sanding (and buffing and polishing), and to collect excess water or cleaning fluid (including dirt suspended in the water or fluid) when machine *7* is used for carpet cleaning.

[0075] To introduce a vacuum attachment, rotary-motion conversion module *2* and machine *7* are modified as follows. Machine *7* and fixed gear housing *202* are modified to further comprise a machine vacuum receptacle *85*, a housing vacuum receptacle *80*, and a vacuum aperture *81*, all allowing air passage therethrough. When rotary-motion conversion module *2* is mated with machine *7* as described earlier in connection with FIGS. 7, housing vacuum receptacle *80* and machine vacuum receptacle *85* are aligned and mated along vacuum alignment line *86* so that a vacuum means (not shown) known in the art can be attached to housing vacuum receptacle *80* and machine vacuum receptacle *85*. When the vacuum means is activated, this will suck air through vacuum receptacle *85*, housing vacuum receptacle *80*, and vacuum aperture *81*, thus creating a vacuum within an interior region *87* of rotary-motion conversion module *2*. Additionally, composite motion pass-through means *210* and operating attachment *101* are respectively modified to include a plurality of composite motion pass-through vacuum apertures *82* and operating attachment vacuum apertures *83*, which are aligned with one another to provide and air flow passage therethrough. Thus, the vacuum created in interior region

87 by attachment of a vacuum means to housing vacuum receptacle *80* and machine vacuum receptacle *85* will additionally suck up air through composite motion pass-through vacuum apertures *82* and operating attachment vacuum apertures *83*. Finally, an optional vacuum skirt *84* attached as illustrated about the circumference of fixed gear housing *202* helps to concentrate the vacuum in a way most desirable to substantially remove dust and other waste products created by sanding, polishing, and buffing, and to substantially remove water and cleaning fluid, along with any dirt suspended therein, for carpet cleaning and similar applications. These waste products are sucked into the vacuum means, and then disposed of in any of a variety of manners well known in the art. It is understood that while these waste products are sucked "into" the vacuum means, that these may or not ultimately remain in the vacuum means prior to disposal. Thus, for example, the vacuum means may comprise a dirt bag as is well known in the art, which accumulates dust and dirt for subsequent disposal along with the bag. Or, for example, the vacuum means may simply be a vacuum pump that causes the dirt (or water / fluid) to pass through the pump and be disposed of in a drum or similar waste receptacle,

by environmentally safe runoff, or in any other manner known in the art for disposing of waste products gathered by means of a vacuum.

[0076] It is to be observed that while the vacuum attachment of FIG. 8 is illustrated in connection with the use of rotary-motion conversion module *2*, that the type of vacuum attachment illustrated in FIG. 8 can be applied to any preexisting sander, buffer, polisher, carpet cleaner and similar machine substantially as illustrated in FIG. 8, even if rotary-motion conversion module *2* is not used. In this alternative embodiment, machine *7* is still modified to include machine vacuum receptacle *85*, operating attachment *101* is still modified to include a plurality of operating attachment vacuum apertures *83*, and bell *71* serves the role of optional vacuum skirt *84* to concentrate the vacuum. All that is eliminated is rotary-motion conversion module *2*, and the modifications made thereto for vacuum purposes as earlier described. A vacuum means is then attached to machine vacuum receptacle *85* as earlier described. When this vacuum means is activated, a vacuum is created which will again suck up air through operating attachment vacuum apertures *83*. This suction will again substantially remove dust and other waste products cre-

ated by sanding, polishing, and buffing, and will substantially remove water and cleaning fluid, along with any dirt suspended therein, for carpet cleaning and similar applications.

[0077] While the various embodiments of this invention have been illustrated using "toothed" wheels, it is fully understood that "friction" wheels are an obvious, equivalent substitute for these wheels, and that this substitution is included within the use of the terms "gear" and "wheel" as defined and utilized in this specification and its associated claims. Similarly, a wide variety of alterations and adjustments to the particular gear interactions illustrated herein, which would be obvious to someone of ordinary skill in the mechanical arts, are encompassed within the scope of this disclosure and its associated claims.

[0078] Finally, while the operating attachment *101* has been described herein generally as a sander, buffer, polisher, or carpet cleaner, this is illustrative, not limiting. Any type of attachment that one ordinarily attaches to a rotating machine to produce a desired effect on a work product such as wood, stone, marble, metal, glass, ceramic, or any other substance to be finished, the work effect of which can be enhanced by introducing eccentric oscillations over

the primary rotary motion, is considered within the scope of the invention as disclosed and claimed. Similarly, any application, whether to wood finishing, stone or marble finishing, metal, glass or ceramic finishing, or any other substance finishing or cleaning, is also considered within the scope of this disclosure and its associated claims.

[0079] While only certain preferred features of the invention have been illustrated and described, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.